EFFECT OF LIME ON SOIL PH, CROP YIELD AND FARM INCOME RESULTS OF EIGHT DEMONSTRATION SITES IN THE NORTHWEST REGION

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ABSTRACT

Eight field scale, lime demonstrations were established in 1985 and 1986, on sites with predominantly strongly acid soils. The purpose of these demonstrations was to determine the economics of liming acid soils and provide information for recommending this practice to farmers. Three rates of lime (low, recommended, & high) were applied at each site using a custom lime spreader. Changes in soil pH, crop yield, and net income were measured annually for up to four years. Soil pH rose dramatically within one year, and remained the same for the remainder of the monitoring period. Crop yield response was much slower, and less dramatic. With all crops (except possibly alfalfa), yield responses were not large enough to recover the cost of liming, even when spreading this cost over a 15 year period.

INTRODUCTION

Past surveys estimate that over 1 million hectares of Saskatchewan soils are strongly acidic. An additional 6 - 7 million hectares are moderately to slightly acidic (Rostad et al., 1983).

Past research on liming acid soils in Saskatchewan has been limited to mainly two studies which obtained somewhat different results. Substantial cereal and oilseed yield increases were found on a strongly acid soil at the Scott Experimental farm (Ukrainetz, 1984). This research involved the use of calcium hydroxide lime on small plots. The usefulness of this information for farmers was limited because calcium hydroxide is not a practical type of lime for farm use. Also the high variability of soil pH in a field made it difficult to apply results from a small plot to a whole field.

In another study where calcium carbonate lime was applied to two field scale sites near Scott, no crop yield increases were found (de Gooijer et al., 1987). However, the soils on these sites were for the most part only moderately acidic.

In Alberta, liming has been tested quite extensively, recommendations have been developed for farm practice, and a lime freight assistance program has been implemented (Penny et al. 1977, Alberta Agriculture, 1984).

Therefore, there appeared to be a need for testing the use of calcium carbonate lime on field scale sites having predominantly strongly acid soils. PFRA initiated a project in 1984 with the sponsorship of the Wilkie Soil Conservation Cooperative. The purpose of the project was to determine the benefit of liming acid soils and develop management information on optimum application rates and most responsive crops.

METHODOLOGY

The project was carried out by PFRA's Rosetown staff. Funding to pay for the liming costs was provided through the ERDA agreement and channelled through the Wilkie Soil Conservation Cooperative. Harold Ukrainetz and Harold Rostad provided much initial assistance in designing the project.

The first step was the selection of sites. This involved investigating recent soil survey reports to find major areas of strongly acid soils, and then contacting interested farmers within these areas. Assistance in this regard was obtained from Harold Rostad, Eric Johnson, and Dave Cubbon. A farmer meeting was held to explain the project and generate interest.

From these efforts a list of prospective cooperators and sites was developed. At each site preliminary soil sampling was done to determine the extent and severity of acidity. Final selection was based on the degree of soil acidity, and uniformity of the soils and landscape. On this basis 8 sites were selected for liming (see Figure I).

At each site 5 treatments were established. These consisted of three lime treatments having low, recommended, or high rates of lime; and two control (no lime) treatments (see Figure II).

FIGURE I:

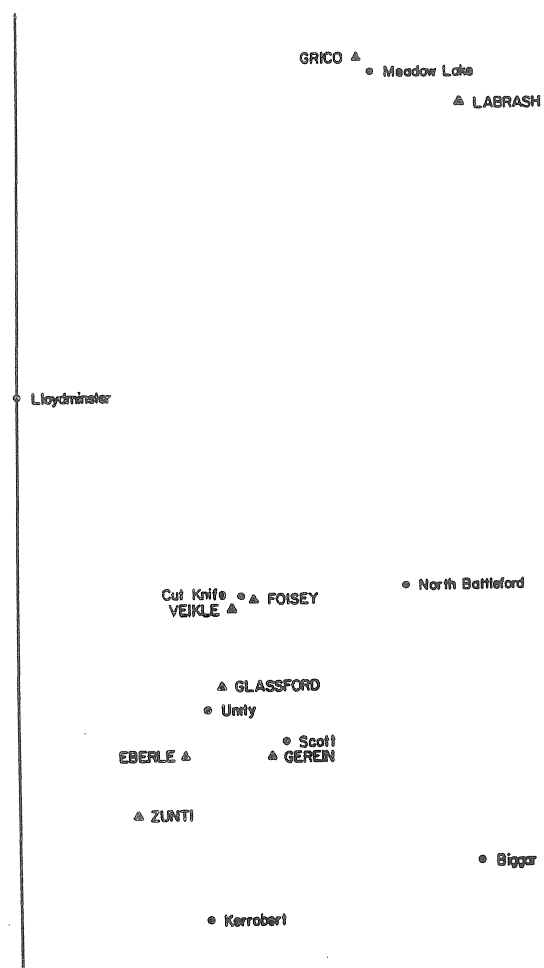
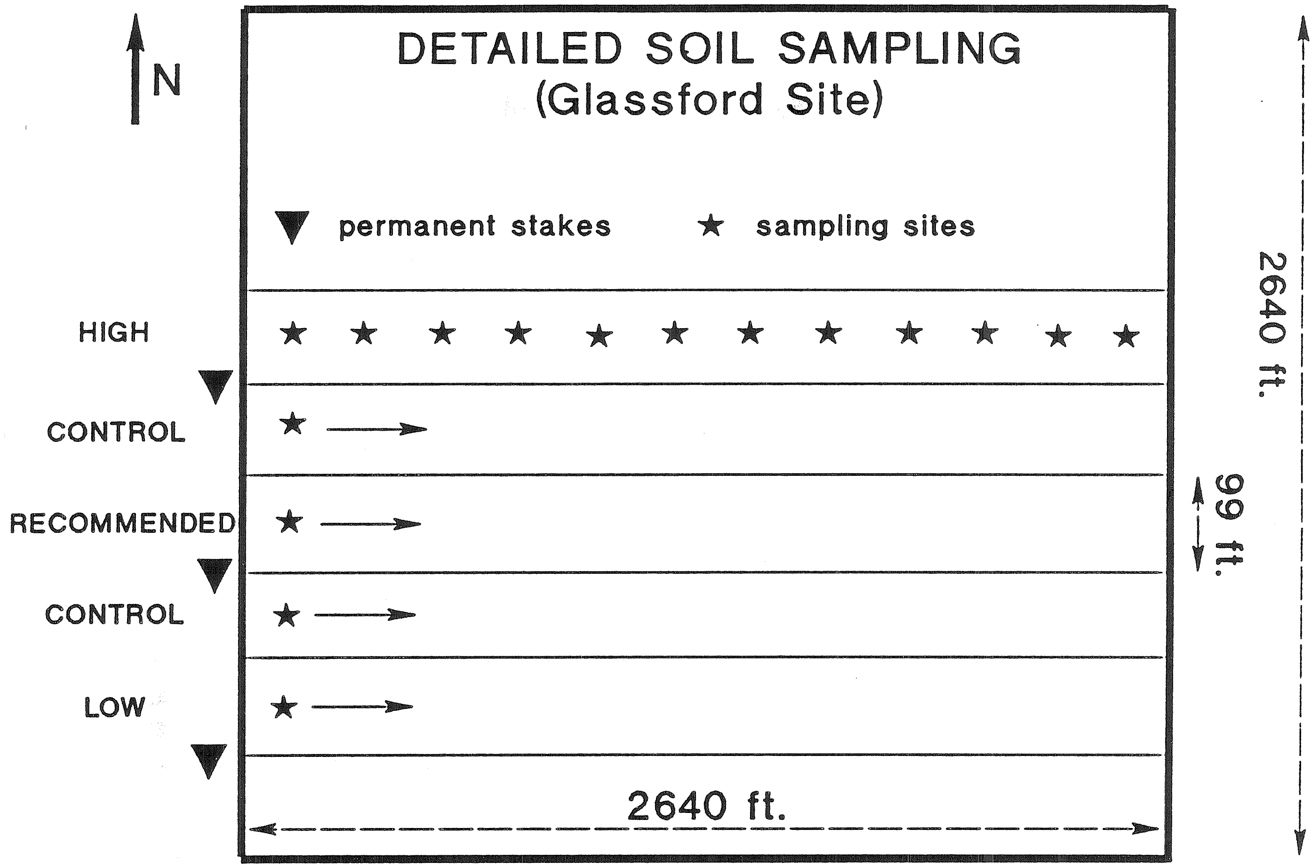


FIGURE II:



At each site 60 soil samples were taken to a 6 inch depth (see Figure II). Each sample consisted of 3 cores taken from about a 2 meter radius. Soil pH was measured to confirm initial uniformity in soil pH between treatments. The measurements were made in 0.01M CaCl2 solution. Composites were made of samples having the most common soil pH. Lime requirement was determined from these composites by adding various amounts of calcium hydroxide lime and measuring the extent to which soil pH was raised. Three rates of lime were calculated based on the amount of lime required to raise the soil pH to 6.0, 6.5, and 7.0 (5.7, 6.2, & 6.7 measured in 0.01 M CaCl2 solution). The rates were adjusted on a ton/acre rate basis for calcium carbonate.

Additional analysis on composite samples included soil fertility, soil texture, organic matter, and cation exchange capacity. These properties helped explain differences in lime requirement for different sites. For example, soils with finer texture and higher organic matter required more lime. Table I outlines the amounts of lime required for each site, and the amount of lime attained.

TABLE I: LIME REQUIRED (req.) & ATTAINED (att.) (ton/acre)

SITE	LOW		RATE RECOMMENDED		HIGH	
	req.	att.	req.	att.	req.	att.
Eberle	1.0	1.3	2.0	2.6	3.0	2.9
Foisey	1.0	1.1	2.0	1.9	3.5	4.3
Gerein	1.0	1.1	2.0	2.4	3.0	2.9
Glassford	1.0	1.1	2.0	2.4	3.5	3.9
Grico	1.0	1.5	2.5	2.4	4.0	3.9
Labrash	1.0	1.3	1.5	1.9	2.0	3.2
Veikle	2.0	1.6	3.5	2.5	5.0	6.5
Zunti	1.0	1.3	2.0	2.6	3.0	2.9

Some samples were also analyzed for aluminum and manganese, since low productivity on acid soils is often associated with toxicities of these elements. A few deeper samples were taken and analyzed for soil pH and calcium content.

Calcium carbonate lime was purchased from Exshaw, Alberta. It was transported by truck, unloaded by blown air, and spread by dribble type lime applicators. The work was done by Hodge Agricultural Lime of Westlock, Alberta. The total cost of liming was $60/ton. The itemized cost was as follows: Lime - $10/ton, Transportation - $30/ton, Unloading & Application - $20/ton.

Four sites were limed in 1985, with the other four in 1986. At six sites the lime was applied after harvest, while at the other two during fallow. At all sites a cultivator was used to incorporate the lime immediately after application. The amount of lime attained was often slightly different than the amount required because of calibration problems with the spreaders. Lime quality was tested by the B.C. Ministry of Agriculture & Fisheries and was found to be excellent.

Soil pH of the top 6 inch layer was measured annually after harvest to determine the effect of liming. Sampling procedure was similar to samples taken before liming. However, samples were not repeated in exact locations from year to year, therefore not allowing for comparison of paired samples. At a few sites composite samples were monitored for changes in soil fertility or subsoil pH.

Crop yield was also measured annually using a weigh wagon. Two swaths from each treatment were measured separately. Each swath ran the full length of the treatment, usually a half mile. In a few situations square meter yield samples were harvested manually, where a weigh wagon measurement was not feasible. These samples followed the same pattern as soil samples. Also, at two sites analysis of canola grain and alfalfa forage was performed for nitrogen and phosphorus content, to determine any effect of liming on nutrient uptake.

Infrared aerial photographs were taken of cropped fields in early July in 1987 and 1988 to identify any differences in crop growth.

RESULTS

1. Soil pH

Average soil pH values (0-6 inch depth) for each treatment, site, and year are shown in Table II. At all sites and treatments soil pH rose significantly within 1 year after liming. Beyond year 1 there were no further increases in pH.

For the recommended and high rates of lime, soil pH did not reach the target levels of 6.5 and 7.0 as expected. Two possible reasons for this could be that not all lime has yet reacted with the soil, or not enough lime was added.

To test this, soil pH of composite samples for each treatment and site were measured at different time intervals over a 4 day period. This test was performed in December 1987, 2 years after liming for four sites and 1 year after liming for the other sites. The results, as shown in Figure III, show that soil pH rose significantly from 30 minutes (normal measurement interval) to 4 days. While the control treatments also rose, the increase was much larger in the lime treatments. This would suggest that not all lime had reacted with the soil in the field at this time. This test also suggests that soil pH should eventually reach target levels, except for possibly the high rate of lime.

Since December 1987, soil pH has not risen substantially. The last samples were taken in the fall of 1988, after a year of below normal rainfall. Perhaps soil pH may increase a bit more after a few more years of normal rainfall.

Results of other soil analyses are outlined below:
1. Aluminum and manganese levels were not toxic to crops.
2. Subsoil pH was higher than surface pH to start with and did not increase after liming.
3. Levels of available phosphorus and nitrogen did not change as a result of liming.

FIGURE III: CHANGES IN SOIL PH WITH TIME
(0.01 M CaCl2 added at time = 0)
(Average of 8 Sites)

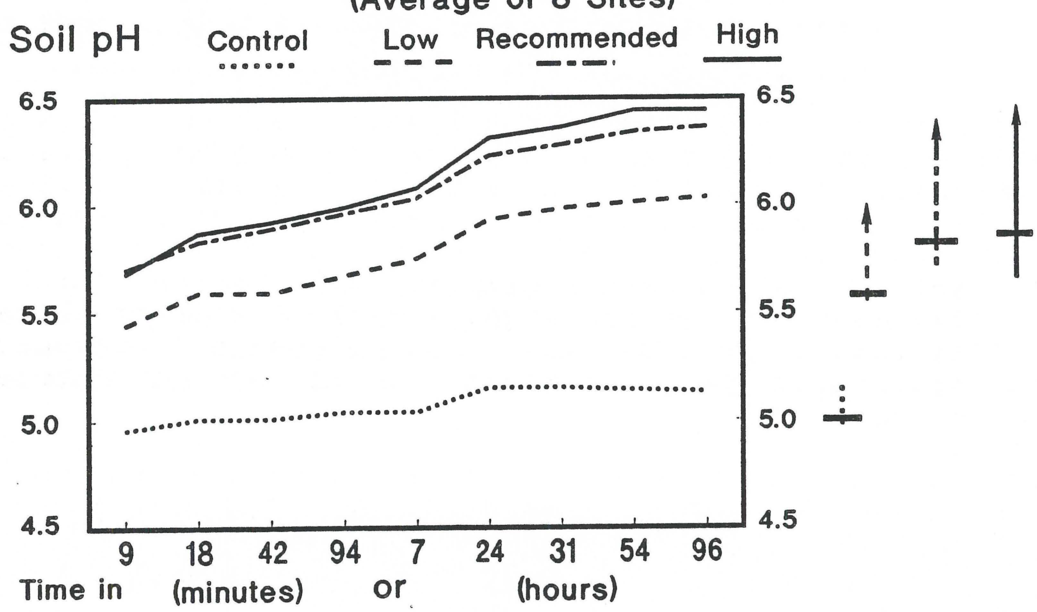


TABLE II: CHANGES IN SURFACE SOIL PH

SITE/YEAR	LOW	CONTROL	LIME RATE RECOMMENDED	CONTROL	HIGH
Eberle					
1986	5.2 de*	5.3 cd	4.7 g	4.8 fg	5.2 de
1987	5.8 ab	5.2 de	5.6 bc	4.9 efg	6.0 a
1988	6.0 a	4.8 fg	5.7 ab	5.1 def	6.1 a
Foisey					
1985	5.1 g	5.0 g	5.1 g	5.1 g	5.0 g
1986	5.5 ef	5.0 g	5.8 cd	5.1 g	6.3 a
1987	5.6 de	5.2 fg	6.0 abc	5.2 fg	6.0 abc
1988	5.5 de	5.2 fg	5.7 cde	5.2 fg	6.2 ab
Gerein					
1985	4.7 fg	4.9 efg	4.9 efg	4.7 fg	4.7 g
1986	5.5 d	5.0 efg	6.3 a	5.0 efg	6.2 ab
1987	5.1 e	4.9 efg	5.7 cd	5.0 efg	5.7 cd
1988	5.5 d	5.1 e	5.9 bc	4.9 efg	5.9 bc
Glassford					
1985	4.8 e	4.9 e	4.9 e	4.8 e	5.0 e
1986	5.7 c	5.0 e	5.9 bc	5.1 de	6.3 a
1987	5.7 c	5.0 e	6.1 ab	5.0 e	6.2 a
1988	5.4 d	4.9 e	5.7 c	4.8 e	5.9 bc
Grico					
1986	5.2 de	5.3 cde	5.3 cde	5.3 cde	5.2 de
1987	5.6 bc	5.3 cde	5.9 ab	5.3 cde	6.0 a
1988	5.5 cd	5.1 e	6.0 a	5.1 e	5.9 ab
Labrash					
1986	4.8 d	4.8 d	4.8 d	4.7 d	4.9 d
1987	5.8 c	4.9 d	6.1 ab	5.0 d	6.3 a
1988	5.6 c	4.9 d	5.6 c	4.8 d	5.9 bc
Veikle					
1985	4.4 gh	4.6 fgh	4.6 fgh	4.3 h	4.7 fg
1986	5.5 cd	4.6 fgh	5.8 bc	4.7 fg	6.1 a
1987	5.1 e	4.7 fg	5.4 d	4.9 ef	5.6 bcd
1988	5.1 e	4.7 fg	5.6 bcd	4.5 fgh	5.9 ab
Zunti					
1986	5.3 b	5.0 bc	5.2 bc	5.2 bc	5.0 c
1987	6.0 a	5.2 bc	6.2 a	5.1 bc	5.9 a
1988	5.9 a	5.2 bc	6.2 a	5.3 b	6.1 a

Note * - Soil pH values having similar small letter designations are not significantly different at the 5% level. Soil pH levels can be compared between treatments and years within 1 site, but not between sites.

2. Crop Yields

Average yields of various crops for each treatment, site, and year are shown in Table III. The results show that for all annual crops there has been little increase in crop yield due to liming. In only 6 out of 54 comparisons between limed and unlimed treatments was there a significant increase.

Comparing the yield differences between different years would suggest that the effect of liming on crop yield has increased with time. For example after the first year 0 out of 24 comparisons had higher yields, while after the third year 4 out of 15 were higher. However, the effect of the lime even after the third year was small.

With alfalfa the effect of liming appears to have been more dramatic. However, not enough sites, treatments, and replications within each treatment have been measured to adequately assess this effect.

Aerial photos taken in past years have shown visible differences in crop growth for only a few cases. These trends correspond fairly closely with crop yield measurements.

Analysis of canola grain and alfalfa forage found no difference in nitrogen and phosphorus levels.

3. Economics

The net benefit of liming (margin) for each treatment, site, and year is shown in Table IV. These values were obtained using actual costs and prices used by the cooperators. For annual crops virtually every case showed a net loss in farm income due to liming, even when spreading the cost of lime over a 15 year period at 11% interest. The only exception was a few instances with the low rate of lime.

The percentage of lime cost recovered by increased yield was on average about 50, 25, and 15 percent for the low, recommended, and high rates, respectively. The losses only slightly decreased with time. By the third year an average of about one-third of the lime costs were being recovered by increased yield.

In Alberta a transportation subsidy is provided, which reimburses farmers for about 80% of transportation costs. For these projects this would amount to about 40% of total costs. In most cases this would still not be enough for farmers to break even with this practice.

For alfalfa there may be an economic benefit to liming, but too few data were attained to be conclusive.

These results suggest that liming is not a recommended practice in Saskatchewan at this time.

TABLE III: CHANGES IN CROP YIELD (bu/acre)

SITE -Crop, Year	LIME RATE LOW	CONTROL	RECOMMENDED	CONTROL	HIGH
Eberle					
-wheat,87	34.8 b*	37.0 a	35.4 ab	33.8 b	
-wheat,88	13.8 a	13.5 a	13.9 a	11.7 b	13.8 a
-fallow,89					
Foisey					
-barley,86	49.1 a	47.8 a	51.8 a	48.7 a	49.1 a
-lentils,87	34.6 b	36.8 a	36.8 a	33.9 b	34.4 b
-peas,88	22.4 a	19.4 b	19.9 b	17.3 c	20.4 b
-canola,89	17.8 a	17.1 a	17.4 a	17.1 a	17.8 a
Gerein					
-wheat,86	47.1 a	47.9 a	47.9 a	45.2 a	50.0 a
-fallow,87					
-wheat,88	28.3 ab	27.0 bc	29.5 a	25.8 c	29.7 a
-fallow,89					
Glassford					
-wheat,86	44.7 a	44.7 a	41.6 a	44.4 a	46.8 a
-wheat,87	28.3 a	26.5 ab	26.9 ab	25.8 b	28.5 a
-wheat,88	13.4 b	13.5 b	14.2 ab	14.1 ab	15.3 a
-fallow,89					
Grico					
-barley,87	73.5 a	70.2 b	73.6 a	75.4 a	71.2 b
-canola,88	47.1 a	43.4 a	43.3 a	41.4 a	42.7 a
-barley,89	76.7 **	75.2	78.5	75.4	75.1
Labrash					
-wheat,87	13.4 a	14.6 a	13.8 a	13.1 a	14.0 a
-oats,88 +	0.99 a	1.03 a	1.08 a	1.07 a	1.12 a
-canola,89	25.1 **	24.4	22.5	24.8	17.3 ++
Veikle					
-wheat,86	42.1 **	---	41.9	41.8	44.5
-lentils,87	yield measurements not obtained				
-alfalfa,88 +	0.50 b	0.55 b	0.50 b	0.49 b	0.73 a
-alfalfa,89	---	---	5.55 **	4.90	5.42
Zunti					
-mustard,87	39.9 a	37.0 b	37.4 b	38.8 ab	39.2 ab
-barley,88	33.5 a	30.3 bc	31.4 b	28.9 c	30.0 c
-fallow,89					

Notes:

* Crops yield values having any small letter designations in common are not significantly different at the 5% level. Comparisons can only be made between treatments in the same year & site.

** These values could not be statistically analyzed since only 1 rep per treatment was measured.

\+ Yields with this designation are expressed in tonne/acre.

++ At this site & year liming caused better crop emergence. However, a killing frost soon after resulted in a lower yield.

TABLE IV: NET BENEFIT OF LIMING ($/acre)

SITE		LIME RATE LOW	RECOMMENDED	HIGH
EBERLE				
Annual Lime Cost:		**10.68**	**21.36**	**23.82**
Net Benefit:	wheat,87	-12.74	-22.17	---
	wheat,88	- 9.98	-20.61	-23.12
	fallow,89	-10.68	-21.36	-23.82
FOISEY				
Annual Lime Cost:		**9.50**	**16.41**	**37.15**
Net Benefit:	barley,86	- 6.78	- 5.05	-34.43
	lentils,87	-14.00	- 7.71	-42.85
	peas, 88	13.99	- 7.42	-25.26
	canola,89	- 5.21	-14.57	-32.86
GEREIN				
Annual Lime Cost:		**9.47**	**20.66**	**24.97**
Net Benefit:	wheat,86	- 7.82	-16.61	-14.62
	fallow,87	- 9.47	-20.66	-24.97
	wheat,88	- 2.91	- 9.96	-13.58
	fallow,88	- 9.47	-20.66	-24.97
GLASSFORD				
Annual Lime Cost:		**9.17**	**20.01**	**32.52**
Net Benefit:	wheat,86	- 8.76	-27.91	-26.49
	wheat,87	- 3.41	-18.27	-26.22
	wheat,88	-10.56	-18.64	-27.35
	fallow,89	- 9.17	-20.01	-32.52
GRICO				
Annual Lime Cost:		**16.29**	**26.06**	**42.35**
Net Benefit:	barley,87	-15.44	-25.10	-44.21
	canola,88	17.17	-19.65	-40.22
	barley,89	-12.09	-16.46	-42.95
LABRASH				
Annual Lime Cost:		**14.12**	**20.63**	**34.75**
Net Benefit:	wheat,87	-15.06	-20.74	-34.45
	oats,88	-17.90	-18.74	-30.34
	canola,89	-10.93	-33.78	-79.42
VEIKLE				
Annual Lime Cost:		**13.77**	**21.51**	**55.94**
Net Benefit:	wheat,86	-12.87	-21.21	-47.84
	lentils,87	yield measurements not obtained		
	alfalfa,88	-15.67	-23.41	-35.99
	alfalfa,89	----	13.59	-28.04
ZUNTI				
Annual Lime Cost:		**10.67**	**21.36**	**23.82**
Net Benefit:	mustard,87	0.36	-23.88	-16.64
	barley,88	- 1.70	-17.22	-22.90

Notes: Annual Lime Cost is the total cost spread over a 15 year period at 11% interest. Net Benefit is the increase in returns for each limed treatment over the average of the two control treatments subtract the annual lime cost.

FUTURE MONITORING

These sites will continue to be monitored in a similar way but not as often. For instance, soil pH will be measured about once every four years. Yield of annual crops will be measured about once every two years. Yield of more responsive crops like alfalfa will continue to be monitored every year until significant trends can be established. All future monitoring will be coordinated by PFRA's Area Soil Conservationist in North Battleford.

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